Docket No. 2001-065-TAP

FLEXIBLE ARCHITECTURE FOR RAIL MOUNTED MULTIPLE ROBOTS IN A STORAGE LIBRARY

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates generally to robotic media storage library systems, and more specifically to a redundant system that includes a plurality of independent robots in the form of robotic pods.

2. Background of the Invention:

The current enterprise class library system contains multiple independent robots for concurrently manipulating multiple media cartridges. The library system comprises an array of media storage cells and media cartridge players. A system of rails is used to guide robotic pods through al of the locations on the array.

Data storage library architectures are shaped to take advantage of robotic efficiency. The robot is often constrained by a pivot point or containment rail, which limits the size and performance of the library and eventually establishes cost/performance levels for a design. Problems are presented as library systems become larger, and computer room configurations sometimes require a site planner to design an installation. Some large systems use pass through mechanisms to pass cartridges between individual silos. The pass through system is implemented because the boundaries of the

library enclosure constrain the maximum size of the system. However, pass through mechanisms may be undesirable for cost and efficiency reasons.

Library enclosure boundaries also create control and communication problems. Connecting together large systems of libraries involves the use of many cables for communication between library control modules, as well as for communication and power between robots and controllers.

Library enclosures typically consist of barrier walls that are designed to enclose the library components (i.e. robots, storage cells, media drives, etc.) and provide data security, as well as provide physical isolation of electrical components and containment of electromagnetic interference (EMI). However, these boundaries inhibit design flexibility and limit the growth of library systems.

Therefore, it would be desirable to have a method for scaling large library systems in a cost effective and efficient manner, while providing a logical way to implement physical media storage walls and connect signal and power supplies to robots and controllers.

SUMMARY OF THE INVENTION

The present invention provides a storage library with a stand-alone guide rail system. The library comprises at least one array of storage cells and a guide rail running along the storage cells. A picker robot is coupled to the guide rail, wherein the robot moves along the guide rail and can manipulate objects within the storage cells. The library also comprises a central power source and controller that controls the movement of the robot. The robot receives power and control only from the central power source and controller directly through the guide rail, without any external input from other components in the library. In one embodiment, multiple library enclosures are connected with guide rails, wherein the guide rails form a single, integrated power and communication connection between the robot and the central power source and controller, independent and exclusive of the separate enclosures.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 depicts a perspective pictorial diagram illustrating the architecture of a single library storage module;

Figure 2 depicts a pictorial diagram illustrating a robotic picker mechanism in accordance with the present invention;

Figures 3A depicts a pictorial diagram illustrating a robotic picker mechanism holding a media cartridge in an extended position, in accordance with the present invention;

Figures 3B depicts a pictorial diagram illustrating a robotic picker mechanism holding a media cartridge in a retracted position, in accordance with the present invention;

Figure 4 depicts a schematic diagram illustrating a stand-alone guide rail system in accordance with the present invention;

Figure 5 depicts a top view, pictorial diagram illustrating a library, with inside and outside curving

connections, in accordance with the present invention; and

Figure 6 depicts a schematic diagram illustrating a stand-alone guide rail system without an enclosure in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The architecture of an automated library system **100** is illustrated in **Figure 1** and contains the multiple independent robots **102** to enable the library system **100** to concurrently manipulate multiple media cartridges **105**. The library system **100** comprises a two-dimensional array of media cartridge storage cells **103** and media cartridge players **104** that are mounted in a frame **101**. A system of rails **121-126** is used to guide robotic pods **102** through all of the locations in the array, which eliminates the need for any steering or guide mechanisms on board the robotic pods **102**, resulting in a reduction in the mass of the robotic pods **102**. The rail system **121-126** also constrains the movement of the robotic pods **102** into horizontal and vertical movements, thereby simplifying the control algorithms for collision avoidance that are required by a typical random moveable object handling system based on horizontal, vertical and diagonal degrees of freedom. The robotic pods **102** contain a moveable carriage that is capable of transporting robotic components, such as media cartridge pickers, bar code reading devices, and other task oriented sub-modules, on the storage library rail system.

As shown in **Figure 1**, the frame **101** is designed to receive a plurality of rows **151-154** of media cartridge storage cells **103**, each of which is designed to house a single media cartridge **105**. The media cartridge players **104** are shown in an arbitrary location in a horizontal

row **155** at the bottom of the frame **101**, although the library system **100** can incorporate media cartridge players **104** at any location in the frame **101** to optimize performance. The robotic pods **102** are attached to the frame **101** via horizontal guide rails **121-126**, which serve to frame the media cartridge storage cells **103** and media cartridge players **104** on the top and bottom sides thereof. **Figure 1** shows an array of media storage cells 103 fully populated with media cartridges **105** of any arbitrary type. The robotic pod guide rails **121-126** provide support of the robotic pods **102** in the vertical direction to oppose the force of gravity, and they also provide a meshing surface of suitable design to impart traction in the horizontal direction for motive transport of the robotic pods **102**. The robotic pods **102** each incorporate a drive means for propulsion in the horizontal direction along the guide rails **121**.

Figure 1 also shows a plurality of vertical elevator assemblies **131-133** that enable the transfer of the robotic pods **102** in the vertical direction. Multiple vertical elevator assemblies **131-133** are shown in **Figure 1** to exemplify the extensibility and redundancy of the invention. Each of the vertical elevator assemblies **131-133** comprise a set of vertical rails **142** that extend substantially from the top of the frame **101** to the bottom of the frame **101**. The vertical rails **142** support a plurality of elevator stations **140**, each of which contain short horizontal rail segments **141A**, **141B** that are identical in cross section to the main horizontal guide rails **121-126**. The elevator stations **140** are held in

suspension by a drive belt **143** which is made to wrap around a drive pulley attached to a vertical drive motor **113** that is located at the top of each elevator assembly **133**. When a vertical displacement is required of any robotic pod **102**, the vertical elevator **140** is scheduled to move in alignment to the appropriate level of rows **151-155** to allow transfer of the robotic pod **102** onto the elevator rail section **141A**, **141 B** from the pair of horizontal rails **121-126** that are juxtaposed and abutting to the elevator rails **141A**, **141B**. Once the robotic pod **102** is located on the elevator station **140**, the drive motor **113** is activated to transport the robotic pod **102** to a selected one of rows **151-155** and thence moves on to the pair of horizontal rails **121-126** that correspond to the selected row. Elevator assemblies **131-133** can carry more than one robotic pod **102** at a time by adding elevator platforms **140** to the elevator assemblies **131-133** or by extending the elevator platform length to accommodate multiple robotic pods **102** on a single elevator station **140**.

Library storage modules such as library system **100** may be placed in enclosures, either singly or in combination.

Referring now to **Figure 2**, a pictorial diagram illustrating a robotic picker mechanism is depicted in accordance with the present invention. A picker sub assembly mounted to a robotic pod base assembly allows for the picking and placing of media cartridges in media cartridge storage cells, media cartridge players and auxiliary slots such as library loading windows. The

robotic pod **200** has a picker assembly **201** mounted on linear guide rails **202** and is extensible by means of a reach drive motor **203** and integral reach drive gear/crank **204** operating with a cam follower **205** arranged to impart linear motion to the gripper assembly **201**. The picker assembly **201** is mounted on a gripper carriage **209** that slides on rails **202**. The picker assembly **201** is actuated by an electromechanical solenoid **206** to open gripper fingers **207** against a spring force from springs **208**. An alternate method (not shown) for gripping the media cartridge would be to provide a cam driven mechanical latching device to eliminate the solenoid **206**, thereby reducing mass and complexity of the picker subassembly **201**.

Referring to **Figures 3A** and **3B**, pictorial diagrams illustrating the operation of a robotic picker mechanism are depicted in accordance with the present invention. The picker assembly **201** is made to constrain the media cartridge **210** in an onboard position or an extended position. **Figures 3A** and **3B** illustrate side views of the robotic pod **200** in the extended and retracted positions, respectively. Thus, the picker mechanism **201** grasps the media cartridge **210** and, when retracted, pulls the media cartridge into the robotic pod **200** to enable transportation of the selected media cartridge **210** to a designated location by the movement of the robotic pod **200**.

Referring to **Figure 4**, a schematic diagram illustrating a stand-alone guide rail system is depicted in accordance with the present invention. The present

invention builds upon the basic robot/guide rail design depicted in **Figure 1**, but allows the guide rail system to provide power and control directly to the robots, independent of the enclosure housing the storage cell arrays.

By using the present invention, guide rail connectivity can incorporate any combination of straight and curved sections to arrive at a fully flexible architecture. The present invention also provides an extensible cabinet structure allowing containment of guide rails and associated media cells and accessories. This allows robots to share cabinet structures utilizing track connectivity to travel across cabinet boundaries, without additional electrical connectivity to the host module, and without additional electrical, optical or other wireless hardware. The guide rails provide integrated power and signal capability for robot power and control, which may be accomplished by means of multiple integrated conductors within the rails.

Referring back to **Figure 4**, a power supply **402** provides power to robotic device **404** via power and ground conductors in rail **403**. A controller **401**, using processor and logic circuits, generates signals for use in controlling the movement and operations of robotic device **404**. The controller **401** is also provided with modulator/demodulator circuitry to encode such communication signals and impress or superimpose such signals onto the power signal provided to the robotic device **404** via the power conductors in rail **403**. Similar modulator/demodulator circuitry is provided onboard robot

404 to recover and decode the signals from controller **401**. Once recovered and decoded, such signals are transmitted to motion controller circuitry onboard robot **404** in order to effect the desired movement and operation.

Robot **404** communicate with controller **401** in the same fashion, thereby providing feedback to the controller **401** concerning movement and operation of the robot **404**, which information the controller **401** may use to generate further control signals. In that regard, such communication signals may be combined with the power signal in any fashion known in the art. For example, because power signals are typically lower frequency signals, communication signals may comprise higher frequency signals. Therefore, the power signal may be filtered out by robot **404** and controller **401** using high-pass filters to recover the communication signals. In such a fashion, high-speed full duplex communication may be implemented between the controller **401** and robot **404** without the need for multiple conductors, cabling, or wireless connection.

Prior art library systems require power and control to be handed off between enclosures as robots move from one enclosure to the next. By contrast, the present invention allows power and control over the robots to remain centralized within the integrated rail system itself. As can be seen in **Figure 4**, the controller **401** and power source **402** are independent of the storage cell array **405** and feed directly into the rail system **403**. The stand-alone nature of the rail system allows the

rails to form customized pathways both within and between library enclosures, while maintaining a standard power and control system that is independent of the particular geometry of a given library system. This allows the guide rails to form complex pathways and geometric configurations, while maintaining uninterrupted power and control signals to the robots.

Referring to **Figure 5**, a top view, pictorial diagram illustrating a library, with inside and outside curving connections, is depicted in accordance with the present invention. The library **500** is comprised of seven enclosures **501-507**, each containing arrays of media storage cells, e.g. cell **511**, and media retrieval robots, e.g., robot **512**. In addition, enclosures **504-506** contain media players **508-510**.

Enclosures **501-503** each have straight guide rails **513-515**, respectively, and outside curving connector rails **516-518**, respectively. Enclosures **504-506** contain inside curving guide rails **519-521**, respectively, an either side of their respective media readers **508-510**. Enclosure **507** contains a long curving guide rail **522**.

While library **500** is comprised of three different enclosure configurations, the guide rails and robots within each respective enclosure form one integrated system, which is independent of those enclosures in terms of power supply and control functions. For example, using prior art methods, robot **512** would be considered a component of enclosure **504**. If robot **512** were to move from enclosure **504** to enclosure **501**, enclosure **504** would remove robot **512** from its inventory of available

components, and enclosure **501** would add robot **512** to its own inventory of available components.

Unlike the prior art, the present invention does not require this handing off of power and control between enclosures **501** and **504**. In the present invention, robot **512** is treated as a component of a single stand-alone guide rail system, and simply moves from one storage cell array to another. Robots are not added or removed from the system inventory unless the robots are physically added or removed from the guide rails.

The use of the present invention allows a single robot **512** to move along the twists and turns of the entire library **500** without any disruption in power and communication. This flexibility is not available with prior art systems, which rely on power and control methods such as cables, optical, infrared (IR), and radio frequency (RF). Cables would become tangled by such twists and turns through library **500**. Optical, IR, and RF systems would be limited by the lack of a continuous line of sight and interference from enclosure walls. Such line-of-sight and interference problems are avoided with the present invention, and physical movement is unrestricted due to the absence of cables.

Referring to **Figure 6**, a schematic diagram illustrating a stand-alone guide rail system without an enclosure is depicted in accordance with the present invention. **Figure 6** represents the most dramatic example of the present invention and takes the present invention to its logical conclusion. As described above, the present invention provides a guide rail system that is

functionally independent of any enclosure or storage cell array in terms of power and control of robotic retrieval devices. Therefore, it is possible to implement a guide rail/robot system that is not contained within a conventional enclosure at all.

In **Figure 6**, the guide rail **601** is mounted directly on two walls **602** and **603** within a building, without an enclosure surrounding the rail. Robots (not pictured) can use the guide rail **601** to retrieve items directly from the walls **602** and **603**. For example, items (e.g., media cartridges) may be placed along walls **602** and **603**. Robots operating on guide rail system **601** can then retrieve these objects. In a sense, the building **600** becomes the enclosure for the library system. **Figure 6** illustrates how the stand-alone guide rail system can be customized to fit almost any geometry needed by the designer.

While the example depicted in **Figure 5** above illustrates how the flexibility of the present invention can be applied using more conventional library enclosures, **Figure 6** illustrates how an integrated library system can be built around the rail system itself, rather than using preexisting enclosures and cell arrays as the starting elements.

In addition to the inside and outside curving paths depicted in **Figure 6**, the present invention also allows the guide rail system to form other types of paths. Examples of these complex paths include sloping paths, upward, downward, diagonal, as well as non-orthogonal paths. Because power and control signals are supplied to

the robots directly through the guide rails, the robots are able to receive uninterrupted power and guidance despite being out of the line of sight of the controller due to the complex paths formed by the guide rails.

The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment was chosen and described in order to best explain the principles of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.